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## (54) IMPROVEMENTS IN AND RELATING TO COMPRESSION REFRIGERATION SYSTEMS

(71) We, AXSTANE PROPERTIES LIMITED (formerly Hall-Thermotank International Limited), a British Company of 242 Vauxhall Bridge Road, London SW1V 1AU (formerly of Regina House, 1—5, Queen Street, London, EC4N 1SS), do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following Statement:—

This invention relates to an improved control device for use in a compression refrigeration system, and in particular to a device in a compression refrigeration system for sensing the presence of liquid in the suction line leading to a compressor.

Compressors used in the refrigeration and air-conditioning industry are primarily designed to pump refrigerants in the vapour and not the liquid state. Although modern compressors can tolerate small proportions of liquid entering the compression chamber via the suction line, the virtual non-compressibility of liquids means that the presence of any substantial proportion of liquid in the compression chamber will impose strain on the moving parts of the compressor and reduce the effective life of the compressor. In an extreme condition, where an appreciable proportion of the material within the compression chamber is in the liquid phase, the compressor can be so extensively damaged that considerable repair costs and extensive down-time for the equipment results.

It is possible to design equipment so that the possibilities of liquid being present in the suction line to the compressor are made very remote, but commonly the closer one can work to the condition at which liquid is on the point of appearing in the suction line, the more efficiently will the plant be operating and there is therefore a need for an accurate sensor which will determine the presence of liquid in the suction line reliably and instantaneously. The condition under which liquid is just appearing in the suction line of a compressor is normally referred to

as the condition of "zero superheat" and this invention is primarily concerned with providing a reliable, cheap and rapidly operating liquid detector for zero superheat.

According to one aspect of the present invention a compression refrigeration system comprises a compressor interposed between a suction line and an outlet duct, a condenser connected to the outlet duct and in which compressed gas is cooled, an evaporator from which expanded gas is fed back to the suction line and an expansion valve between the condenser and the evaporator and a control device comprising a thermistor located in the suction line of the system, means for supplying electrical energy to the thermistor to raise its temperature above that of the gas intended to flow in the suction line, audible and/or visual alarm means and an actuator means for the alarm means which actuator means is responsive to changes in the resistance of the thermistor.

Conveniently the alarm means is arranged to be actuated when the resistance of the thermistor differs by more than a pre-set amount from a pre-determined value and possibly to remain actuated for a timed interval thereafter.

It will be appreciated that in normal operation of a compression refrigeration system, the suction line (which includes the inlet duct to the compressor) contains cold gas and, at its end closest to the actual compression chamber(s) of the compressor ought not to contain any appreciable quantities of liquid. In use of the device, the thermistor is in contact with the gas flowing in the suction line and is operated under conditions of "self-heat" at a temperature above that of the cold gas in the suction line. When it is contacted by a drop of liquid, rapid evaporation of the liquid is caused by contact with the heated thermistor, and this will occasion a sharp decrease in temperature of the thermistor by virtue of the latent heat of vaporisation of the liquid having to be drawn from the thermistor. The temperature drop will cause

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a significant change in the resistance of the thermistor which is sensed by the actuator means and employed to actuate the alarm. Alarm indication can be used to summon an operator to make some adjustment to the system to remove the cause of the liquid in the suction line.

If desired, the resistance change, demonstrated by the thermistor when contacted by liquid, may also be used to turn off the compressor or to bleed hot gas from the outlet duct of the compressor directly into the suction line. This bleeding of hot gas into the suction line may be effected via an on/off solenoid valve controlled by-pass linking the outlet of the compressor and the suction line, the solenoid valve being opened and shut by a relay in series with the thermistor. This opening of the solenoid valve allows a proportion of the hot gas in the outlet duct of the compressor to flow into the suction line, the hot gas mingling with the cold gas and causing rapid vaporisation of any liquid droplets in the suction line.

Conveniently the on/off solenoid valve will be placed in series with a manually settable flow-rate control valve so that the rate at which gas can by-pass the condenser, the expansion valve and the evaporator of the system, can be determined empirically and can be set at a suitable value. Suitably a timer is employed in the actuator means, and it is convenient to set this so that the solenoid valve remains open for a few minutes (say three minutes) on the appearance of a resistance change of the thermistor indicating the presence of liquid in the inlet duct to the compressor. The use of a timer in this way prevents the solenoid valve "hunting" (i.e. being opened and closed too frequently) which occurrence might damage the solenoid valve.

Instead of using a manually settable valve in series with an on/off solenoid valve, a modulating valve may be employed in the by-pass line in series with the solenoid valve this modulating valve being controlled by a sensing device determining the temperature of the gas in the outlet duct of the compressor. Such an arrangement can be used to ensure that the temperature of the gas in the outlet duct of the compressor does not exceed a predetermined maximum value.

The connection between the by-pass and the outlet duct of the compressor may be made as close to the compressor as is deemed desirable but the connection between the by-pass line and the suction line should be made as close to the outlet of the evaporator as possible, in order to allow the maximum distance for intermingling of the hot gas from the by-pass with the cold gas/liquid flowing through the outlet of the evaporator before the mixture reaches the

compression chamber(s) of the compressor.

Preferably the thermistor is located as close as possible to the compression chamber(s) of the compressor and may indeed be mounted actually in the casing of the compressor.

Conveniently the thermistor is mounted in a short connecting member which can be inserted in any chosen orientation between a flange on the compressor casing, defining the inlet of the compressor, and a flange defining the end of the pipe leading from the outlet of the evaporator. Ability to be able to adjust the orientation of the connecting member means that in any particular case the thermistor can be positioned where it is most likely to be contacted by liquid in the suction line.

A further aspect of the invention relates to a method of operating a compression refrigeration system to reduce the possibility of liquid refrigerant being drawn into the compressor which method comprises positioning a thermistor in the suction line leading to the compressor, supplying electrical power to the thermistor to raise its temperature above that of the gas phase in the suction line, sensing the resistance of the thermistor and using the sensing of a change in the resistance of the thermistor by more than a pre-set amount from a pre-determined value to actuate an audible and/or visual alarm and optionally also to stop the compressor.

The invention will now be described, by way of example, with reference to the drawings accompanying the provisional specification, in which:—

Figure 1 shows one form of thermistor probe for employment in a control device in accordance with the invention.

Figures 2 and 3 show two possible circuit arrangements for employment with the probe of Figure 1, and

Figure 4 shows a schematic indication of a compression-refrigeration system employing a thermistor controlled by-pass line.

Referring to Figure 1, a thermistor 4 is shown mounted in a probe body 1 screwed into a threaded hole 10 formed in an annular body 11 forming part of the suction line of a compression-refrigeration system. The body 1 shrouds the thermistor 4 and adjacent its open end is provided with holes 1' allowing a sample of the gas/liquid flowing in the body 11 to flow past the thermistor 4. A joint ring 6 seals the body 1 to the body 11.

The thermistor 4 is supported by short connecting wires 3 attached to the conducting leads of a cable 8. The wires 3 are located in passages 12 in an electrically insulating plug 2. The passages 12 are filled with a set electrically and thermally insulating compound which bonds the wires 3 in place leaving the thermistor 4 firmly

supported on the plug 2 in a manner which electrically and thermally insulates it from the bodies 1 and 11. The cable 8 is locked in the body 1 by a gland nut arrangement 5. A region of the body adjacent to the plug 2 contains a sealant 7.

The body 11 may be part of the inlet duct formed in the casing of a compressor. Alternatively, the body 11 can be a duct connecting the outlet of an evaporator with the inlet of a compressor. In the arrangement illustrated, the body 11 is an annular housing which fits between a pair of flanges, one defining the inlet to the compressor casing and the other defining the downstream end of the duct from the evaporator outlet. The holes 13 shown in Figure 1 are positioned to correspond with the holes in the pair of flanges so that the orientation of the body 1 relative to the horizontal can be adjusted depending on how the housing is positioned between the flanges.

Figures 2 and 3 shows circuit arrangements for use with a negative-coefficient thermistor 4.

Figure 2 shows an arrangement of actuator circuit which will stop (energised via a main contactor C) a compressor, when a liquid sensing relay (LSR) switches over from one stable state to the other operating switch contacts 21 and 22. A green light "g" is illuminated when the resistance of the thermistor 4 is low (say 20 ohms in the presence of only refrigerant vapour in the inlet to the compressor) but a red light "r" (and optionally also an audible alarm "aa") is actuated when the resistance of the thermistor 4 rises sharply (say to 200 ohms) when liquid refrigerant contacts it. The coil resistance of the liquid sensing relay LSR used, in a typical case, would be 2000 ohms. The chain line in Figure 2 represents a control box casing, the items shown within the chain line being located in the casing. The green and red lights are visible through the casing.

Figure 3 shows a modified form of actuator circuit in which a timer (TME) is used to hold open a solenoid valve (SV) in a bypass line 20 (see Figure 4) whenever unvaporized liquid refrigerant is detected in the suction line 13 to the compressor C in a compression refrigeration system. The evaporator of the system is shown at 15, the condenser at 16 and the expansion valve at 17. A manually settable valve 18 is shown in series with the solenoid valve SV in Figure 4.

#### WHAT WE CLAIM IS:—

1. A compression refrigeration system comprising a compressor interposed between a suction line and an outlet duct, a condenser connected to the outlet duct and in which compressed gas is cooled, an evaporator from which expanded gas is fed

back to the suction line and an expansion valve between the condenser and the evaporator, and a control device comprising a thermistor located in the suction line of the system, means for supplying electrical energy to the thermistor to raise its temperature above that of the gas intended to flow in the suction line, audible and/or visual alarm means and an actuator means for the alarm means which actuator means is responsive to changes in the resistance of the thermistor.

2. A system as claimed in claim 1, in which the thermistor is mounted in a screw-threaded supporting probe body, the thermistor being electrically and thermally insulated from the probe body.

3. A system as claimed in claim 2, in which the probe body shrouds the thermistor and is provided with holes allowing gas/liquid to pass therethrough to contact the thermistor.

4. A system as claimed in any preceding claim in which the thermistor is mounted in an annular body adapted to be located between two flanges in the suction line.

5. A system as claimed in any preceding claim employing a thermistor as illustrated in Figure 1 of the drawings accompanying the provisional specification.

6. A system as claimed in any preceding claim in which the alarm means and actuator means are housed together in a casing, the alarm means being a warning light.

7. A system as claimed in claim 6, in which two warning lights are provided in the casing one energised when liquid is not sensed by the thermistor and the other energised when liquid is sensed by the thermistor.

8. A system as claimed in any preceding claim in which the alarm means and actuator means are substantially as illustrated in Figure 2 of the drawing accompanying the provisional specification.

9. A method of operating a compression refrigeration system to reduce the possibility of liquid refrigerant being drawn into the compressor which method comprises positioning a thermistor in the suction line leading to the compressor, supplying electrical power to the thermistor to raise its temperature above that of the gas phase in the suction line, sensing the resistance of the thermistor and using the sensing of a change in the resistance of the thermistor by more than a pre-set amount to actuate an audible and/or visual alarm.

10. A method as claimed in claim 9, in which the sensing of a change in resistance of the thermistor is used to stop the compressor.

11. A method as claimed in claim 9, in which the sensing of a change in resistance

of the thermistor is also used to control a valve in a hot-gas by-pass line interconnecting the output and input of the compressor.

- 5 12. A method as claimed in claim 11, in which the valve in the hot-gas by-pass line is opened on the appearance of a resistance change of a pre-set amount and then remains open for a predetermined period.
- 10 13. A method of operating a compression refrigeration system to reduce the possibility of liquid refrigerant being drawn into the compressor substantially as hereinbefore described using the device illustrated in
- 15 Figures 1, and 2 of the drawing accompanying the provisional specification.
14. A method of operating a compression

refrigeration system to reduce the possibility of liquid refrigerant being drawn into the compressor substantially as hereinbefore described using the device illustrated in Figures 1, 3 and 4 of the drawing accompanying the provisional specification.

15. A compression refrigeration system substantially as hereinbefore described with reference to, and as illustrated in Figure 4 of the drawing accompanying the provisional specification.

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